27. PALEOLATITUDES AND MAGNETOSTRATIGRAPHY OF CRETACEOUS AND LOWER TERTIARY SEDIMENTARY ROCKS, DEEP SEA DRILLING PROJECT SITE 585, MARIANA BASIN, WESTERN CENTRAL PACIFIC[1]

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ABSTRACT

Coring in two adjacent holes at DSDP Site 585 (13.5°N, 156.8°E) recovered lower Tertiary through Aptian sedimentary rocks. The paleolatitudes of each hole from the late Aptian through Paleocene were derived from an extensive set of paleomagnetic minicores. Each sample underwent progressive thermal demagnetization, and the characteristic direction of magnetization was derived from the region of stable directions. True mean inclinations were computed for each lithologic unit and for each stage or pair of stages, using the method of Kono (1980b). The results yield average paleolatitudes of 1°S for the Paleocene–Maestrichtian, 7°S for the Santonian–Turonian, and 15°S for the Albian–late Aptian. The Aptian–Albian paleolatitudes agree with paleomagnetic results from DSDP Sites 462 and 289 in the western central Pacific. The average rate of northward drift by the site was about 30 km/m.y. through the Late Cretaceous and earliest Tertiary. The Maestrichtian paleolatitude agrees with a Pacific paleomagnetic pole computed by Gordon (1982) from North Pacific data, but the site is about 12° farther north than predicted by Campanian and Cenomanian North Pacific poles (Gordon, 1983; Gordon and Cox, 1980).

Recovery of the latest Cretaceous–early Tertiary sediments was inadequate to allow unique determination of the magnetostratigraphy. No reversed interval could be identified within the late Aptian or early Albian.

INTRODUCTION

Site 585 of DSDP Leg 89 was drilled in the East Mariana Basin of the western Pacific (13.5°N, 156.8°E). Two adjacent holes (585 and 585A) bottomed in mid-Cretaceous volcaniclastic turbidite sediments. The emphasis of the paleomagnetic sampling and analysis was on determination of the site's paleolatitudes from the Aptian to the present. Magnetostratigraphy was of limited usefulness because of the poor recovery and condensed nature of the uppermost Cretaceous and Tertiary sediments.

The results are summarized separately for each sedimentary unit. The preliminary paleomagnetic results in the Site 585 report (this volume) were based on shipboard measurements of natural remanent magnetization (NRM) and shore-based measurements after partial demagnetization; in many cases, the final results after complete thermal demagnetization treatment are significantly different.

METHOD

Using a drill press, an average of two paleomagnetic minicores (2.5 cm diameter, 2.4 cm length) were taken from each 1.5-m section of recovered sedimentary rock from Cores 26 through 55 of Hole 585 and from Cores 1 through 22 of Hole 585A. These were drilled perpendicular to the axis of the core. The deviations of the holes from vertical were measured during drilling with a downhole Kuster instrument or after drilling by observing the tilt of laminae in the sediments (Hole 585); the direction of deviation was determined from the paleomagnetic measurements and treated as a "structural correction" to the mean inclination (as discussed later).

Shipboard measurements of NRM were made using a Digico spinner fluxgate magnetometer. This instrument has a 2 to 3° drift within a set of 5 measurements, and displayed fluctuating sensitivity for samples having magnetization intensities of less than 10^{-2} A/m (10^{-5} emu/cm^3), possibly as a result of the changing orientation of the sensors with respect to the ambient field as the ship rolled in the seas. Three months later, NRMs were remeasured on shore after the samples had been stored in a magnetic-field-free space for several days; in nearly every case the new NRM directions indicated loss of a downward component, but showed no change in declination. This is interpreted as the partial removal, during transport and storage, of a viscous remanent magnetization (VRM) vector oriented in the direction of the present-day field at Site 585 (the mean dipole inclination is +25.6°, but the present field has an inclination of 12.0° and a deviation from true north of 5.0°E; present field intensity is 0.35 gauss).

Shore-based analyses and demagnetizations were conducted in a steel-shielded room (internal field less than 1000 gammas) at the University of Wyoming. Depending on the intensity of magnetization, measurements were made on a Schonstedt spinner magnetometer (using 3 or 6 sample orientations) or a two-axis ScT cryogenic magnetometer (using 8 sample orientations: 90° rotation about Z axis and inverse set, with 2 measurements in each orientation); both instruments were on-line to a minicomputer. Supplemental samples were analyzed on an ScT cryogenic magnetometer at the California Institute of Technology. The background noise level of the cryogenic magnetometers is equivalent to 2×10^{-6} A/m (2×10^{-9} emu/cm^3) for a 10-cm^3 sample. For any demagnetization step, none of the sample intensities was less than 5×10^{-4} A/m, that is, two orders of magnitude greater than the noise level.

Demagnetization procedures varied for each lithology, depending upon the results from pilot samples. Alternating-field (AF) demagnetization was performed on a single-axis Schonstedt AF demagnetizer. Thermal demagnetization was done in non-inductively wound furnaces with separate cooling chambers. In general, each sample was analyzed at eight demagnetization steps to determine the stability of the characteristic direction of magnetization.

The DSDP cores in general have no horizontal orientation control, so one has only magnetic inclination to indicate polarity. For sediments deposited at middle to high paleolatitudes (over 15° from the equator), inclination data alone are adequate; but for samples deposited at low paleolatitudes, long-period secular variation and the uncertainties associated with collection and analysis of the samples cause inclination data to be ambiguous in many cases. Site 585 was predicted to be in the vicinity of the equator during the earliest Tertiary. There-

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fore, the directional change of the magnetization vector during demagnetization was also used as an indicator of the polarity (e.g., a declination shift of 180° between the NRM and the stable characteristic directions was presumed to imply removal of a normal-polarity present-day secondary overprint from a primary reversed direction).

During progressive thermal demagnetization, every sample of every lithology displayed removal of a downward component of magnetization (probably VRM by the present field) at the early heating steps, followed by an interval in which a stable direction was maintained as the intensity of magnetization decreased. This region of stability was considered to be the characteristic (primary or original) direction of magnetization. A mean characteristic direction for each sample was computed by averaging the results of the three to six thermal demagnetization steps defining this interval of stability. This direction was rated A, B, or C according to the standard deviation: less than 1.5° = A; 1.5 to 3° = B; over 3° or uncertain polarity = C. For most of the paleolatitude calculations, only A-rated values were used.

The true mean inclination, paleolatitude, and associated precision parameters were computed following the method of Kono (1980a, b) for calculating statistics of inclination data from unoriented vertical drill cores. This method uses the mean and standard deviation of the sines of the inclinations to compensate for the circular Gaussian (Fisherian) distribution of paleomagnetic vectors. A simple mean of the inclinations gives unrealistic importance to the higher values. Using the mean and standard deviation of the sines, the true mean inclination I and circular dispersion parameter K were measured (from chart in Kono, 1980b, p. 3881). The other parameters were computed as follows (Kono, 1980a, except as noted):

Radius of circle of 95% confidence interval on the true mean inclination =

$$\alpha_{95} = \cos^{-1}\{1 - [20^{1/(N-1)} - 1][(N - 1)/(K - 1)N + 1]\},$$

where N = number of samples.

Radius of circle of standard deviation (63% confidence interval) = $\alpha_{63} = 0.58 \times \alpha_{95}$ (McElhinny, 1973, p. 80).

Paleolatitude of the site = $\phi = \tan^{-1}(0.5\tan I)$.

Confidence intervals on paleolatitude =

$$d\phi = 0.5\,(1 + 3\sin^2\phi)\,dI$$

where $dI = \alpha_{95}$ or α_{63} of I, as desired.

Recently, Cox and Gordon (1984) derived another method for computing mean true inclinations from drill-core data. Unlike the method of Kono (1980b), which used the Fisherian circular distribution of the magnetization directions, the method of Cox and Gordon uses a Fisherian distribution of the projected poles (virtual geomagnetic pole, or VGP), as would result from secular variation; this distribution would be seen as an egg-shaped distribution of the directions of magnetization. The Cox and Gordon method is applicable with high precision to instantaneous directions—for example, from basalt flows, which are sampling discrete points on the curve of secular variation—whereas the Kono method seems more applicable to directions from sediment samples, which have an inherent averaging of several hundred years of secular variation and should have a Fisherian distribution. For turbidite sediments, such as those in the Albian–Aptian portion of the section at Site 585, deposition was essentially instantaneous, but the magnetic direction is set over a much longer interval of time as the sediment dewaters and undergoes grain-grain compaction (as discussed later). Therefore, the statistical method of Kono would also apply to data from turbidites.

TIMING AND RELIABILITY OF CHARACTERISTIC REMANENCE

Two major uncertainties in analyzing the paleomagnetism of sedimentary rocks are whether the primary magnetization is revealed by the demagnetization procedure and whether the direction of this primary magnetization is identical to the ambient magnetic field at the time the sediments were deposited. Unfortunately, it is difficult to demonstrate that the correlative two conditions of reliability are satisfied for an outcrop or a drilled section of sedimentary rock; the arguments are largely circumstantial, and usually rely on experimental evidence, downhole variation in magnetization, magnetic properties, agreement with other studies, and other evidence. plus some degree of unsupported intuition. It is beyond the scope of this chapter to review all aspects of this topic; a more detailed treatment may be found in textbooks and recent review papers (e.g., Lowrie and Heller, 1982, for marine limestones, and Champion et al., 1984, and Coe et al., in press, for clastic and turbidite sediments).

The direction of magnetization obtained from paleomagnetic analysis of a rock is termed "characteristic" because it is often impossible to demonstrate that it is the primary direction unaffected by persistent overprints. The technique of identifying characteristic directions and overprints by using progressive demagnetization was developed in the 1970s (reviewed by Kirschvink, 1980). Many types of sedimentary rocks, especially those containing goethite or hematite diagenetic minerals, require thermal demagnetization to remove secondary overprints; alternating-field (AF) demagnetization can have negligible effect on such overprints (e.g., Steiner, 1977). Many of the early paleomagnetic studies of DSDP sedimentary rocks relied on low-intensity, single-step AF demagnetization of samples, so the identification of characteristic directions of magnetization is uncertain in many cases. Some secondary overprints may never be completely removed, or are removed simultaneously with the primary magnetization. Some of the processes and diagenetic minerals responsible for secondary remanences, and the methods for identifying these minerals, are reviewed by Henshaw and Merrill (1980), Lowrie and Heller (1982), and Tucker and Tauxe (1984). One common technique for identifying persistent overprints is to display on vector diagrams the direction and magnitude of magnetization during progressive demagnetization (reviewed by Kirschvink, 1980). Such a technique was employed in this study. One method to remove such overprints is to compute the mean vectors of characteristic magnetization of the normal and reversed polarity samples independently, then compute a weighted mean based on the relative intensities (Ogg, 1981; van Alstine and Ogg, unpublished; Steiner et al., in press); this method could not be applied at Site 585, owing to the lack of mixed polarity in most of the lithologic units.

The next problem is to determine when this characteristic magnetization was acquired. Experimental evidence indicates that magnetization of sedimentary rocks is acquired mainly during post-depositional early compaction (dewatering) and consolidation, and not at the time of deposition (Verosub, 1977; Hamano, 1980; Denham and Chase, 1982; Tucker, 1984; reviewed by Champion et al., 1984). In the studies just cited, the post-depositional remanent magnetization appears to be aligned with the ambient field; this is in contrast to a shallower magnetic inclination ("inclination error") present in some unconsolidated or varved sediments (King, 1955; Griffiths et al., 1960; Coe et al., in press). Deep-sea sediments have not shown any systematic inclination error (Opdyke and Henry, 1969), and fine-grained sediments with bioturbation and low to moderate sedimentation rates are generally considered to be reliable recorders of the magnetic field. The depth at which the post-depositional remanence is fixed is a function of compaction, void ratio, grain sizes, intensity of bioturbation, and sedimentation rate; it can range from 2 to 60 cm below the sediment/water interface, corresponding to a delay on the order of 10^4 yr. (Løvlie, 1974, 1976; Verosub, 1977). This offset in timing between the paleontological age of a sediment and the setting of magnetization is usually ignored in magnetostratigraphic studies. In a study of limestones deposited under oxidizing conditions, Channell et al. (1982) observed that the magnetization carried by authigenic hematite began to be fixed before the magnetization carried by magnetite grains was locked in by sediment compaction, but the oxidation process continued to a depth of 60 cm below the "lock-in" zone (equivalent to about 10^5 yr. in these limestones). Therefore, the characteristic magnetization carried by hematite in marine sediments deposited under oxidizing conditions can also be used as a reliable indicator of the magnetic field present shortly after deposition.

Coe et al. (in press) conclude that sandstones and coarse siltstones are less reliable recorders of the magnetic field because post-depositional remanence may not be completely acquired and some depositional inclination error may be retained. In a study of clastic turbidites at DSDP Site 524, Tucker (1984) observed that the coarser-grained portions have less reliable characteristic magnetizations than the finer-grained portions; he concluded that this phenomenon was due to the freedom of small magnetite grains to realign in void spaces for a considerable time after deposition, whereas there was an early "locking in" of the magnetite during consolidation of the finer-grained sediments. Champion et al. (1984) also concluded that fine-grained portions of turbidites yielded reliable results, whereas the coarse-grained portions had a larger proportion of viscous remanent magnetization (VRM). They did not observe any significant difference (at 95% confidence interval) between the inclinations of bioturbated vs. nonbioturbated fine-grained portions of the clastic turbidites. In a study of calcareous turbidites, Alvarez and Lowrie (1984) observed no significant difference between the coarse- and fine-grained portions, perhaps indicating locking of magnetite orientations by partial cementation of the sediment soon after deposition. On the basis of these studies, it is thought that the fine-grained portions of turbidites recovered at Site 585 are reliable recorders of the geomagnetic field soon after deposition.

Clay-rich laminated sediments may experience a shallowing of inclination during late-stage compaction, according to Coe et al. (in press), who cite, however, only two possible instances in which this may have occurred (Creer, 1974; Liddicoat and Coe, 1979). This effect is theoretically caused by the rotation of magnetite grains during compaction (Blow and Hamilton, 1978). No sedimentary rocks at Site 585 are the clay-rich laminated types in which "compaction error" is thought to occur.

In summary, the progressive thermal demagnetization and associated vector-analysis procedure used in determining characteristic magnetization directions of the sedimentary rocks at Site 585 are probably identifying the magnetization acquired a short time after deposition of the sediments and recording the ambient field at that time. This verdict is based largely on the circumstantial evidence already summarized and on the lithologies and magnetic properties of the rocks to be described shortly. As will be shown, the reliability of the true mean characteristic directions at Site 585 is further supported by the agreement of those directions with the paleolatitudes computed from data on basalts at nearby Site 462.

RESULTS

The magnetic characteristics, polarity zonation, and mean inclinations of the sample sets are presented according to the lithologic units described in the site report.

Unit 1: Gray Siltstone (lower Miocene)

Sampled cores: 585A-H1 (wash)
Depth: Uncertain, probably between 10 and 250 m
No. of samples: 4

The interval between 7 and 256 m sub-bottom depth was not cored in either hole at Site 585, so samples were taken from large pieces of gray siltstone, dated as early Miocene, which were recovered in a wash core spanning this interval in Hole 585A. These pieces are probably from the center of a thick, clastic turbidite bed, so they encompass only a very brief time span.

The mean NRM intensity is $9 \pm 3 \times 10^{-3}$ A/m (9×10^{-6} emu/cm^3, with a mean inclination of $20 \pm 10°$. Progressive thermal demagnetization at ten steps from 110 through 510°C produced a region of fairly stable directions in the interval from 230 to 470°C. The mean intensity in this interval is $6 \pm 2 \times 10^{-3}$ A/m. A pilot sample heated to 600°C retained a fairly stable direction, with a final intensity of 9×10^{-4} A/m, suggesting that hematite (Curie temperature = 670°C) is a carrier of magnetization, perhaps in addition to magnetite (Curie temperature = 570°C).

Characteristic directions were computed by a fit to five steps between 230 and 470°C (tabulated in Appendix). Because the standard deviation for the inclinations was about 2° for each sample, these characteristic directions were rated B in reliability. Polarity is normal for all samples. The true mean inclination is 10.7°N, with a 95% confidence limit of 3.7° and a dispersion parameter, K, of 500. This paleolatitude is not considered representative of the early Miocene, because there are only four samples and all are from a single turbidite bed.

Unit 2: Pinkish Tan Nannofossil Chalk and Limestone and Reddish Brown Zeolitic Claystone (middle Eocene to Maestrichtian)

	Hole 585	Hole 585A
Sampled cores	15–17	1–3
Age	late Paleocene–Maestrichtian	early Eocene–Maestrichtian
Depth (m)	367–391	364–384
No. of samples	13	13

The magnetic characteristics of the chalk and limestones and the claystones were generally similar, except that the claystones had stronger average intensities at each demagnetization step. Intensities of NRM average about 8×10^{-3} A/m for chalks and limestones and about 20×10^{-3} A/m for claystones, but the standard deviations are very high. NRM inclinations were positive for all samples, and ranged from 1 to 72°.

A normal (downward) overprint was rapidly removed during early steps of progressive thermal demagnetization, with resolution of normal and reversed polarities possible at the 185°C step, and a stable characteristic direction was maintained between 230 and 510°C. Progressive AF demagnetization to 5 mT (50 Oe) was not as effective in removing overprints as thermal demagnetization at 150°C. During removal of the overprint, the intensity would increase or decrease depending upon the polarity of the sample (Fig. 1). This behavior was also used as a guide to the polarity of some samples. In the interval of stable directions between 230 and 510°C, intensities would generally decrease by a factor of 2. A sharp drop in intensity occurred at 550°C, and in many cases was accompanied by a major dispersion of the directions of magnetization. This suggests that magnetite is the main carrier of the characteristic magnetization.

The inclinations of characteristic magnetization were very shallow, indicating the proximity of the site to the paleo-equator during the Paleocene and Maestrichtian. In most cases, interpretation of polarity is based on behavior during demagnetization; but several samples had uncertain polarity, and their inclinations, despite stability, are rated C. The true mean inclination (Table 1) of this lithologic unit in Hole 585 is 0.1° if all data are used and 0.6° if only A-rated values are used (the 95% confidence interval is about 4.7° in either case); this implies an average paleolatitude for this unit of 0.05 to 0.3°N (with 95% confidence interval of 2.3°).

The true mean inclination computed for this lithology in Hole 585A is approximately −1.0° (with a large 95% confidence interval of 9.7°); the corresponding average paleolatitude is 0.5°S.

An equatorial crossing by Site 585 during the Paleocene–Maestrichtian is indicated; the distribution of inclination data suggests early Paleocene as the closest approximation to the timing of this event (Table 2).

The low recovery of this lithology in Hole 585 precludes assignment of magnetochrons to the few episodes of normal and reversed polarity. A *possible* assignment of magnetozones to the polarity intervals in Hole 585A is indicated in the table of inclinations of characteristic directions (Appendix); the assignments are based on the biostratigraphic ages of the cores and the correlations with the magnetic-polarity time scale of Harland et al. (1982) (which is similar to the scale of Lowrie and Al-

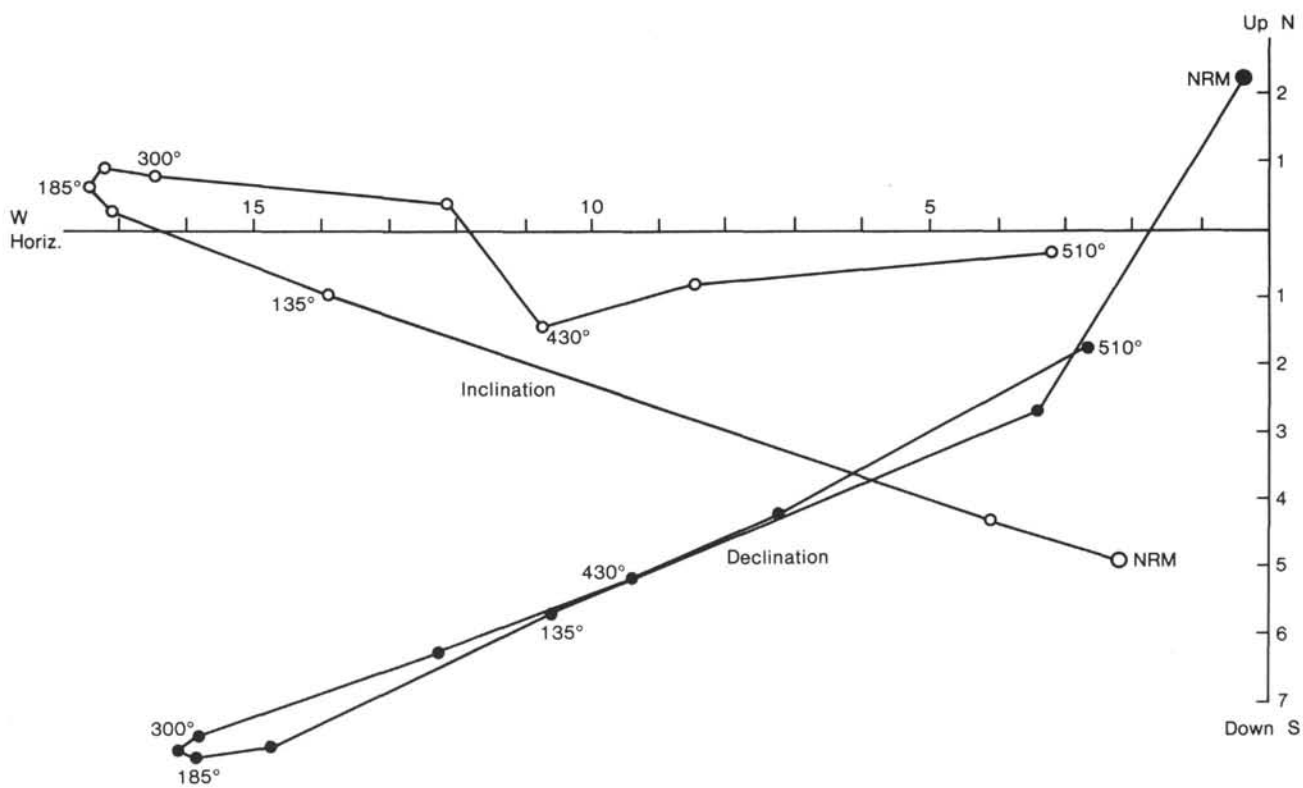

Figure 1. Vector plot of thermal demagnetization of a sample of reddish brown zeolitic claystone (585-16-1, 72 cm; Paleocene; lithologic Unit 2). 1 scale div. = 10^{-3} A/m (10^{-6} emu/cm^3). Inclination (up, horiz., down) is plotted with total magnitude of magnetization at the given demagnetization step; declination (N, W, S) is plotted as the horizontal component of the magnetization vector, and it has arbitrary direction because of lack of orientation control on DSDP cores. Every second demagnetization step is labeled. NRM is dominated by an overprint, which is removed by thermal demagnetization of 200°C; further heating reduces intensity of magnetization but does not significantly change direction. A reversed polarity is indicated for this sample.

Table 1. True mean inclinations of lithologic units.

Unit: lithology (age)	Hole (sample set)	N	I (degrees)	α_{95}/α_{63}	K	Lat. (degrees)	α_{95}/α_{63}
1: Gray siltstone (e. Mio.)	585A (All)	4	10.7	3.7/2.1	500	5.4	1.9/1.1
2: Pink-tan nanno-chalk (Eoc.-Maest.)	585 (All)	13	0.1	4.8/2.8	70	0.05	2.4/1.4
	585 (A)	10	0.6	4.6/2.7	100	0.3	2.3/1.3
	585A (All)	13	−0.8	9.7/6.7	18	−0.4	4.9/2.8
	585 (A, B, Paleoc.-Maest.)	8	−1.2	9.7/6.7	30	−0.6	4.9/2.8
3: Red-brown zeolitic claystone (Maest.-l. Camp.)	585 (A, B)	12	−6.0	7.5/4.3	32	−3.0	3.8/2.2
4: Chert and brown claystone (Camp.-l. Sant.)	585 (All)	3	−9.9	22.9/13.3	23	−5.0	11.7/6.8
5: Dark gray claystone (Sant.-l. Alb.)	585 (All)	54	−14.4	3.1/1.8	40	−7.3	1.6/0.9
	585 (A, except 27-3, 50 cm)	43	−14.7	3.5/2.1	38	−7.5	1.9/1.1
	585A (All)	19	−15.6	5.0/2.9	43	−7.9	2.7/1.5
	585A (A)	16	−15.7	5.1/3.0	50	−8.0	2.7/1.6
6: Dark gray volc. turbidites (Alb.-Apt.)	585 (All)	54	−26.6	3.5/2.0	31	−14.1	2.1/1.2
	585 (A)	39	−26.4	3.3/1.9	48	−13.9	1.9/1.1
	585A (A, B)	52	−30.5	3.4/1.9	35	−16.4	2.1/1.2
	585A (A)	32	−27.1	3.8/2.2	45	−14.4	2.2/1.3

Note: True mean inclinations as computed by method of Kono (1980b). These do not include a correction for the deviation of the hole from vertical. Results are given for all samples in set and for only the most reliable directions (A-rated set). N = number of samples; I = mean true inclination; α_{95} and α_{63} = intervals of 95% confidence and 63% confidence (standard deviation), respectively, on the inclination; K = dispersion parameter; Lat. = paleolatitude (α_{95}/α_{63} = 95% and 63% confidence intervals on Lat.).

varez, 1981). The Cretaceous/Tertiary boundary, as defined by biostratigraphy in each hole, does not appear to fall within the expected reversed-polarity magnetochron 29R, indicating either very poor recovery of the K/T boundary sediments or the lack of the actual boundary at this site (or that the K/T boundary is not synchronic, which is unlikely).

Unit 3: Reddish Brown Zeolitic and Nannofossil Claystones and Tan Clayey Nannofossil Chalk (Maestrichtian to upper Campanian)

	Hole 585	Hole 585A
Sampled cores	18–20	No recovery
Depth (m)	399–422	
No. of samples	13	

Lithologic Unit 3 is distinguished from Unit 2 by the predominance of claystone over chalk; otherwise, the component lithologies are essentially identical. The tan marly chalks were sampled preferentially for paleomagnetism because they were less friable. The magnetic characteristics and demagnetization behavior are the same as those already discussed for these lithologies under Unit 2. The magnetic behavior of a typical tan marly chalk during progressive thermal demagnetization is diagrammed in Figure 2.

All samples have normal polarity. This is consistent with the long episodes of normal polarity during the late Campanian to early Maestrichtian (magnetochrons 32 and 33). The short reversed-polarity interval of magnetochron 32R, within the early Maestrichtian, was not identified, possibly owing to the poor recovery in these three cores.

Inclinations of characteristic magnetization are low but generally negative, indicating that the site was slightly south of the equator during the deposition of Unit 3. The true mean inclination is −6.0° (95% confidence interval of 7.5°), yielding an average paleolatitude of 3.0°S (Table 1).

Unit 4: Chert and Brown Zeolitic Claystone (Campanian to upper Santonian)

	Hole 585	Hole 585A
Sampled cores	21 and 26	Inadequate recovery
Depth (m)	426–485	
No. of samples	3	

Table 2. Paleolatitudes of Site 585.

Age (avg. Ma)	Hole, cores (sample set)	N	(pre-tilt) I (degrees)	α_{95}	(tilt corr.) I (degrees)	α_{95}	K	Lat. (degrees)	α_{95}/α_{63}
Present	585							13.5	
e. Mio. (20) (not plotted)	585A H1 (All)	4	10.7	3.7	9.0	4.7	500	4.5	2.4/1.4
l. Paleoc. (57.5)	585 15 to 16-1, 72 cm (All)	7	−0.6	8.1	−0.6	8.1	50	−0.3	4.0/2.3
e. Eoc.–e. Maest. (60)	585A 1 to 3 (A, B)	8	−1.2	9.7	−3.9	10.7	30	−2.0	5.4/3.3
Maest. (69)	585 16-1, 111 cm to 20-2, 89 cm (A)	15	−2.4	6.5	−2.4	6.5	33	−1.2	3.3/1.9
Camp.–Sant. (80)	585 20-3, 12 cm to 28 (A)	19	−14.2	6.4	−16.7	7.2	27	−8.5	3.8/2.2
Sant.–Coniac.–Tur. (87)	585 26 to 32-2, 107 cm (A)	30	−14.9	4.7	−18.7	5.8	31	−9.6	3.1/1.8
Sant.–Tur.–l. Cenom. (88.5)	585A 5 to 10 (A)	16	−15.7	5.1	−17.9	6.5	50	−9.2	3.5/2.0
Cenom. (84)	585 32-3, 113 cm to 35 (A)	11	−11.5	2.9	−15.3	4.0	230	−7.8	2.1/1.2
m.–l. Alb. (103)	585 36 to 45 (A)	14	−24.8	5.5	−28.6	6.6	50	−15.2	4.0/2.3
e. Alb.–l. Apt. (112)	585 46 to 55 (A)	28	−26.9	3.8	−30.7	4.9	50	−16.5	3.0/1.8
e. Alb.–l. Apt. (112)	585A 5H to 22 (A)	32	−27.1	3.8	−27.8	4.3	45	−14.8	2.6/1.5

Note: Age given as biostratigraphic stage and as absolute age (in millions of years; from time scale of Harland et al., 1982) of midpoint of time spanned by sample set. Reliability of selected sample set (A-rated, etc.) as given. N = number of selected samples; I = true mean inclination (with 95% confidence interval, α_{95}) as computed before and after correction for deviation of hole from vertical (see text); K = dispersion parameter; Lat. = calculated paleolatitude (with 95% and 65% [standard deviation] confidence intervals, α_{95} and α_{63}).

Recovery of lithologic Unit 4 was extremely poor, and only a few blocks were obtained for oriented paleomagnetic minicores. The range of lithologies, from brown claystone to tan chalk, displayed magnetic properties identical to those of the similar lithologies in Units 2 and 3 (Units 2, 3, and 4 differ only in the relative amounts of component lithologies). No cherts were analyzed.

Polarity of characteristic magnetization is normal; the negative inclinations indicate (before correcting for deviation of the hole from vertical) a paleolatitude for the site of about 5°S (with a 95% confidence limit of 12° resulting from the low number of samples). The reversed polarity magnetochron 33R of early Campanian age was not identified, probably because of the extremely sparse sampling.

Unit 5: Dark Gray to Dark Brown Claystone with Minor Pinkish Tan Limestone (Santonian to upper Albian)

	Hole 585	Hole 585A
Sampled cores	27–37	5–10
Depth (m)	484–590	503–554
No. of samples	54	19

The dominant lithology of Unit 5 is a dark gray claystone with variable concentrations of recrystallized radiolarians. NRM intensities were high, generally in the range of 4 to 10 $\times$ 10^{-2} A/m. A slow steady decrease of the intensity of magnetization occurred during progressive thermal demagnetization; the intensity at the 370°C step was typically 50% of NRM, and at the 510°C step was typically 25% of NRM. Pilot samples displayed a sharp drop in intensity between 550 and 600°C, implying that magnetite is the principal carrier of magnetization. Hematite is also a carrier, as indicated by the significant portion (10%) of NRM intensity remaining at the 600°C step, but the directions were identical to those at 500°C. During early stages of thermal demagnetization, the inclinations gradually steepen upward (become more negative), a behavior interpreted as indicating the removal of an overprint of the downward-directed present field. The magnetic behavior of a typical sample is diagrammed in Figure 3.

In the lower part of this unit (Cores 585-34 to 585-37 and 585A-9 and 585A-10), the majority of the paleomagnetic samples are from pinkish tan limestone intervals. Intensities of this lithology were less than for the claystones, which were sampled preferentially in the upper part of this unit; otherwise there was no discernible

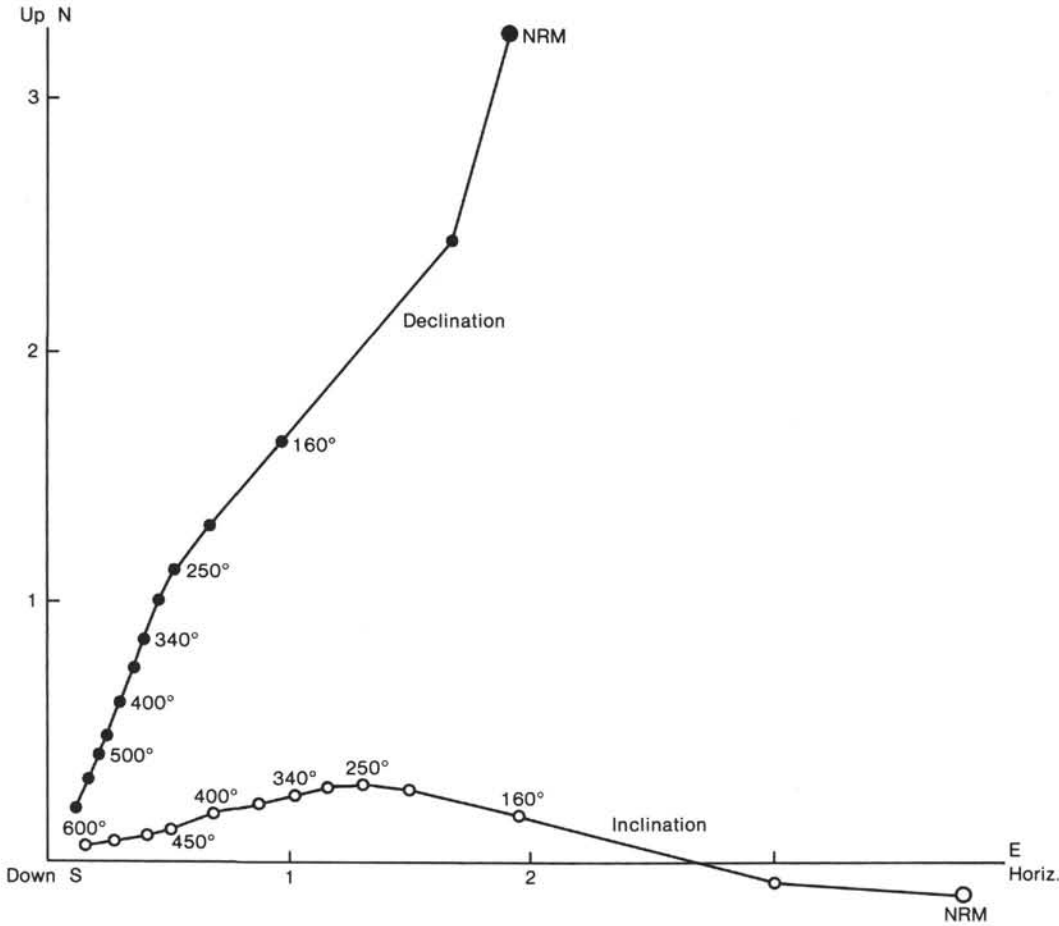

Figure 2. Vector plot of thermal demagnetization of a sample of tan marly chalk (585-20-2, 49 cm; upper Campanian; lithologic Unit 3). 1 scale div. = 10^{-2} A/m (10^{-5} emu/cm^3). (Vector-plot axes and symbols are explained in the caption to Fig. 1.) NRM is dominated by an overprint, which is removed by thermal demagnetization of 250°C; further heating reduces intensity of magnetization but does not significantly change direction. A normal polarity is indicated for this sample.

difference between the two lithologies in their magnetic behavior during demagnetization.

Characteristic inclinations were computed as the mean value of the inclinations at the five demagnetization steps between 300 and 510°C. Several of these mean inclinations were classified as B in reliability because of larger standard deviations or slow, steady drift. True mean inclinations for all samples and for the set of high-reliability A-rated samples are both given in Table 1. The computed average paleolatitudes (before tilt correction) during this time interval are 7.5°S for Hole 585 and 8.0°S for Hole 585A.

Polarity is normal for all but four samples. On the basis of the behavior during demagnetization the "reversal" of two of these samples (585-28-5, 34 cm and 585A-7-4, 37 cm) may result from inversion during collection. However, two adjacent samples from Section 585-27-3 have positive inclinations and display behavior during demagnetization interpreted as reflecting the removal of a normal overprint from a reversed characteristic direction. Such a very brief interval during the Santonian is not known in the current magnetic-polarity time scale, so its reality is suspect; alternatively, these two samples may record a brief excursion of the magnetic field.

Unit 6: Dark Gray Volcanogenic Turbidites (middle Albian to upper Aptian)

	Hole 585	Hole 585A
Sampled cores	38–55	H5; 11–22
Age	m. Alb.–latest Apt.	e. Alb.–l. Aptian
Depth (m)	590–764	658–893
No. of Samples	54	53

Both holes at Site 585 bottomed within a very thick sequence of graded beds of dark gray and greenish black coarse sandstone to silty claystone. Paleomagnetic sampling was done preferentially within the finer-grained tops of these volcanogenic turbidites and within the rare interbedded pelagic claystones. As explained earlier, the coarse-grained portions of turbidites generally are not considered to be reliable recorders of the magnetic field (Tucker, 1984; Champion et al., 1984). Measurements on the few sand-rich intervals that were sampled supported that caveat; the characteristic inclinations had con-

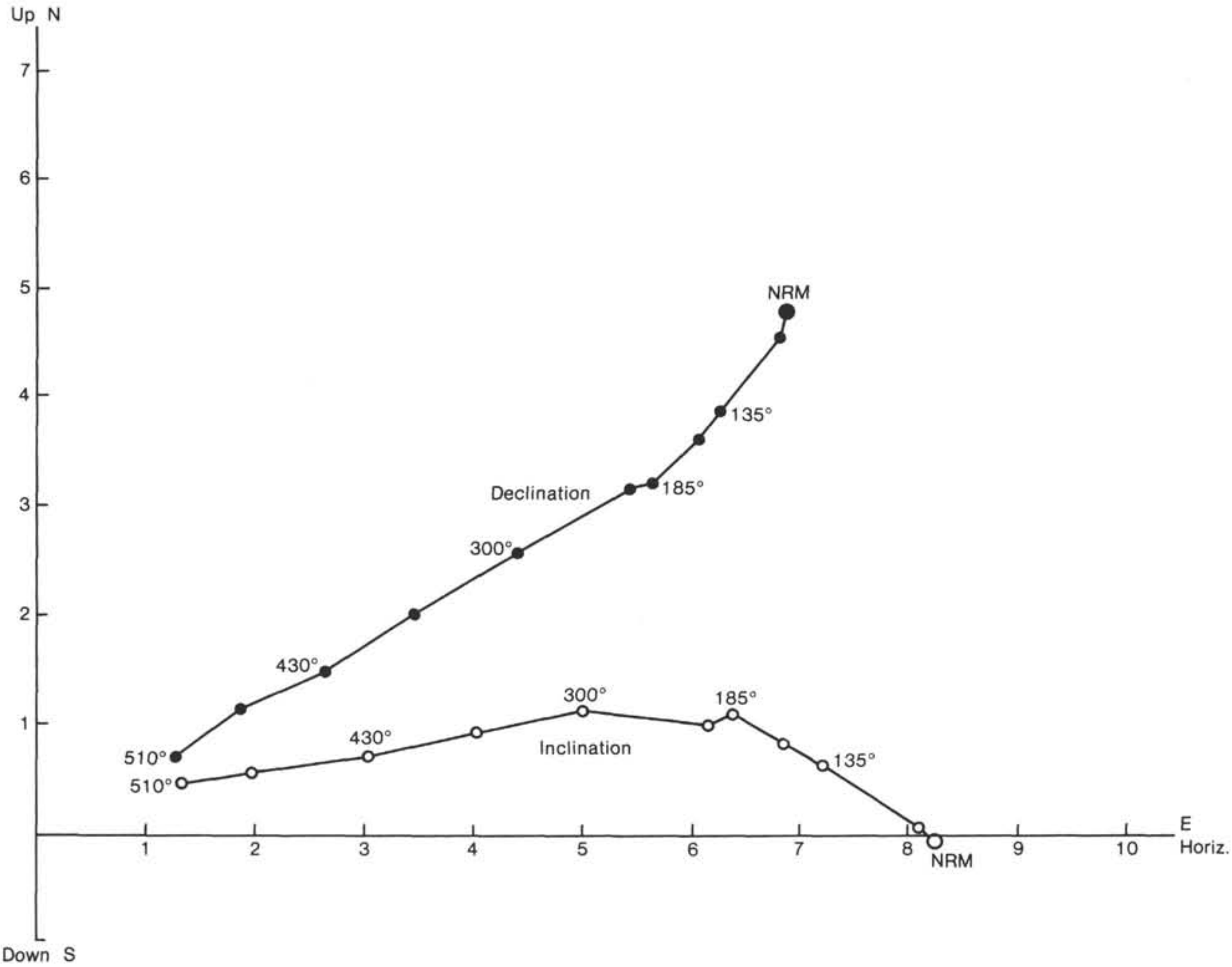

Figure 3. Vector plot of thermal demagnetization of a sample of dark gray claystone (585-28-5, 8 cm; Santonian; lithologic Unit 5). 1 scale div. = 10^{-2} A/m (10^{-5} emu/cm^3). (Vector-plot axes and symbols are explained in the caption to Fig. 1). NRM has a significant overprint, which is removed by thermal demagnetization of 300°C; further heating reduces intensity of magnetization but does not change direction. A normal polarity is indicated for this sample.

siderably more scatter, yielded some anomalous values, or did not attain a stable inclination.

NRM intensities are very strong, generally within 1 to 8×10^{-1} A/m (1 to 8×10^{-4} emu/cm^3); some samples approach 2 A/m. Most NRM inclinations were negative and had a mean of $-20 \pm 3°$. On the basis of the effects of both progressive AF and thermal demagnetization on pilot samples, a combined treatment of AF demagnetization at 5 mT (50 Oe) and thermal demagnetization at 150, 250, and 325°C was applied to the entire sample set. Either treatment (AF or thermal) resulted in an upward steepening of the inclinations (to more negative values), with only slight changes in declination. This is interpreted as indicating the removal of an overprint of present dipole field from a primary normal-polarity direction, with negative inclinations resulting from a southern paleolatitude. Stable directions were generally observed in the pilot samples with the 200 to 450°C or the 10- to 20-mT range of demagnetization steps (Fig. 4). Intensities of magnetization decreased only slightly, up to either 15 mT or 250°C; the intensity at 20 mT or 325°C was generally half of the NRM intensity; and the intensity at 525°C was 10% of the NRM value.

Two samples (585-42-2, 57 cm and 585-53-2, 94 cm) were analyzed on a Curie balance, and the results are shown in Figure 5. Both samples had Curie points of 565°C. Sample 585-42-2, 57 cm, from the claystone upper portion of a turbidite, and including the fine-grained base of the overlying turbidite, displayed a reversible curve, implying that magnetite is the predominant magnetic carrier. Sample 585-53-2, 94 cm (from a dark brown, slightly bioturbated top of a turbidite) had a slightly irreversible Curie run with a greater saturation magnetization upon cooling and with a small ripple in the heating curve. This behavior may indicate the presence, in addition to magnetite, of a small amount of relatively unoxidized titanomaghemite that reverts to magnetite upon heating.

Inclinations of characteristic magnetization are negative for all samples. This is consistent with the extended interval of normal polarity, "Cretaceous Long Normal Interval," of the Aptian–Albian through Santonian stages.

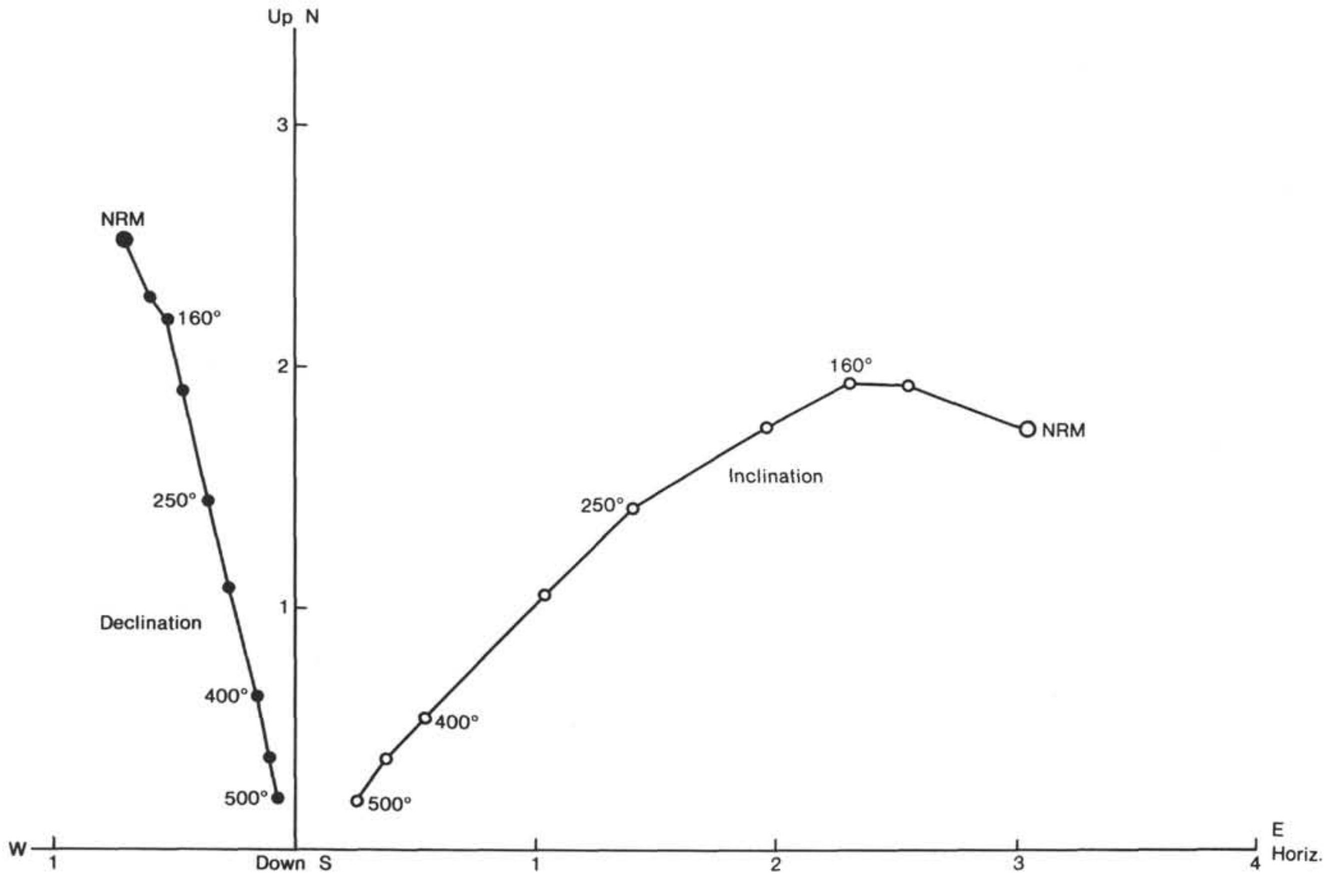

Figure 4. Vector plot of thermal demagnetization of a sample of bluish black clayey siltstone from a volcanogenic turbidite (585-51-4, 25 cm, lower Albian; lithologic Unit 6). 1 scale div. = 10^{-1} A/m (10^{-4} emu/cm^3). (Vector-plot axes and symbols are explained in the caption to Fig. 1.) NRM has a significant overprint, which is removed by thermal demagnetization of 160–250°C; further heating reduces intensity of magnetization but does not change direction. A normal polarity is indicated for this sample.

Several samples from Cores 14 and 15 of Hole 585A displayed positive inclinations of NRM during the shipboard analyses; at that time, these were interpreted as representing a late Aptian mixed-polarity interval. Brief, but uncorrelatable, reversed-polarity events have been observed in upper Aptian to lower Albian sediment (Pechersky and Khramov, 1973; Jarrard, 1974; Keating and Helsley, 1978a, b; Lowrie et al., 1980; Vandenberg and Wonders, 1980; Khramov, 1982, p. 147) and possibly observed as a short marine magnetic anomaly in the Pacific (the anomaly younger than "CL" [MO?] modeled by Hilde et al., 1976) and in the Atlantic (M"-1" of Vogt and Einwich, 1979). This possible mixed-polarity zone in Hole 585A completely disappeared, however, during the early demagnetization steps, as the anomalous NRM inclinations reverted to the negative inclinations of characteristic magnetization typical of adjacent cores. With a total of nearly 80 minicores from the two holes at Site 585, covering the late Aptian to early Albian interval, this study represents a rather dense stratigraphic sampling. If there are any reversed-polarity episodes of this age, then these must be very brief. This initially erroneous interpretation of NRM results was a valuable lesson in the dangers of inadequate demagnetization of DSDP samples.

The true mean inclination of the volcanogenic turbidite lithologic unit is about 27° in both holes (95% confidence interval of about 3.5°), yielding an average paleolatitude of 14°S (Table 1). Correction for the slight deviation of the holes from vertical increases the paleolatitude to about 15°S.

PALEOLATITUDES OF SITE 585

Correction of Inclinations for Deviation of Holes from Vertical

Hole 585 had a 1° deviation from vertical at the level of Core 15, as measured by a Kuster downhole instrument, but the Kuster malfunctioned in later runs for deeper cores. The beds below Core 26 displayed a 5 ±1° tilt of laminae and contacts; this is thought to reflect an increased deviation of the drilling from vertical. The direction of tilt of these laminae, with respect to the axis of the paleomagnetic minicore, was recorded for several samples during drilling. Comparison of the declinations of characteristic magnetization of a few normal-polarity minicores with the relative tilted orientation of laminae in those minicores (as illustrated in Fig. 6) yielded an average apparent tilt declination of 320 ±20° with respect to the direction of normal polarity (assumed to be north-

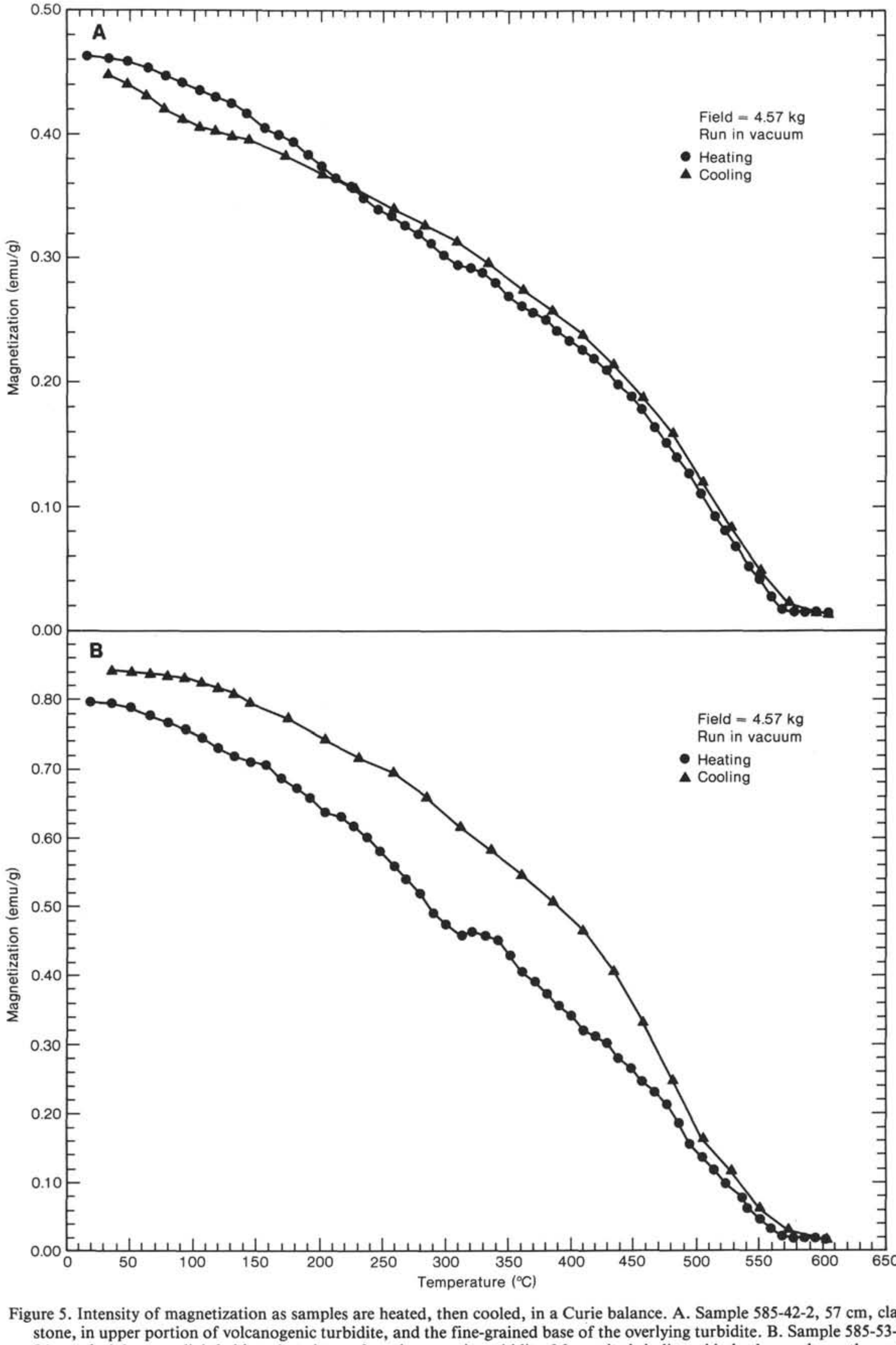

Figure 5. Intensity of magnetization as samples are heated, then cooled, in a Curie balance. A. Sample 585-42-2, 57 cm, claystone, in upper portion of volcanogenic turbidite, and the fine-grained base of the overlying turbidite. B. Sample 585-53-2, 94 cm, dark brown, slightly bioturbated top of a volcanogenic turbidite. Magnetite is indicated in both samples as the main carrier of magnetization, and the presence of a small amount of titanomaghemite is indicated in 585-53-2, 94 cm by intensity of the cooling curve exceeding the heating curve and by the small ripple in the heating curve.

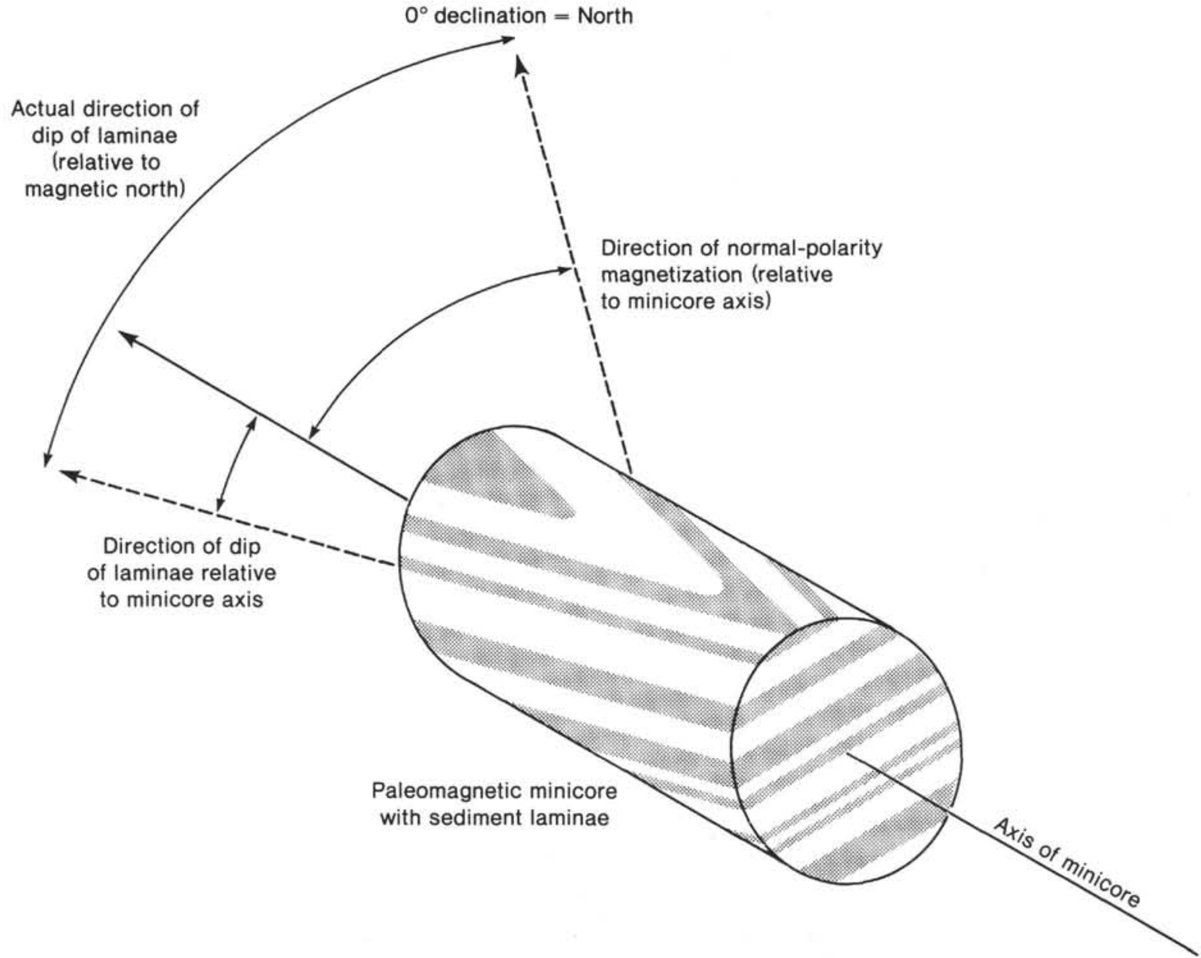

Figure 6. Procedure to determine the direction of deviation of the DSDP hole from vertical, using the relative orientation of the apparent dip of laminae to the direction of magnetization of a normal-polarity sample. The direction of dip of the laminae, as measured counterclockwise from the axis of the minicore cylinder, is added to the apparent declination of the normal-polarity magnetization, as measured clockwise from the axis of the minicore cylinder; the sum is the dip direction of the laminae relative to northward polarity (assumed to have a declination equal to 0°). This value is the same as the compass direction of the deviation of the hole from vertical. For computation of the actual inclination of magnetization, this is nearly identical to a bedding correction (structural correction), with the direction of bedding equal to this declination of the apparent dip of the laminae.

directed, 0° declination). The hole therefore deviates toward this direction. Correction for the tilt of the hole is identical to a structural correction for bedding with a 5° (±1°) dip toward 320° (±20°); the effect of the correction is to tilt the north-directed inclinations upward (to more negative values) by 5° × cos (320 ± 20°) = 3.8° (±1.1°). In Table 2, this correction and increase in uncertainty is applied to the true mean inclinations for Cores 26 and below.

Hole 585A had measured deviations from vertical of 3.5° above Core 5, 4.5° at Core 6, and 1.5° at Core 14 and below. The relative direction of this tilt was determined as 299 ±20° on the basis of of seven laminated samples in Core 5H (a wash core above Core 11). Therefore, the true mean inclinations were given a correction upward and an increase in error limits of 1.7° (±1.0°) above Core 5, 2.2° (±1.4°) for Cores 5 through 10, and 0.7° (±0.5°) for Cores 5H through 22.

It is interesting that if the Deep Sea Drilling Project would deliberately drill holes with a 10 to 15° deviation from vertical, then the apparent tilt of the laminae in the paleomagnetic minicores would provide a means to compute the relative declination of each sample in the set; then the magnetostratigraphy could be determined by both inclination *and* declination of the characteristic directions from these samples. Such a procedure was used successfully to analyze the magnetostratigraphy of DSDP Site 603 in the western Atlantic (Ogg, in press).

Paleolatitudes

Table 2 is a compilation, by age interval, of the mean true inclinations and paleolatitudes for both holes at Site 585. The paleolatitudes are graphed in Figure 7. The conversion of biostratigraphic ages to million of years is based on the Harland et al. (1982) time scale. (For the Late Cretaceous, this time scale is similar to the Lanphere and Jones [1978] revision of the radiometric age scale of Obradovich and Cobban [1975].) The uncertainties in the mean age of each paleolatitude were arbitrarily set as ± one quarter of the total time interval spanned

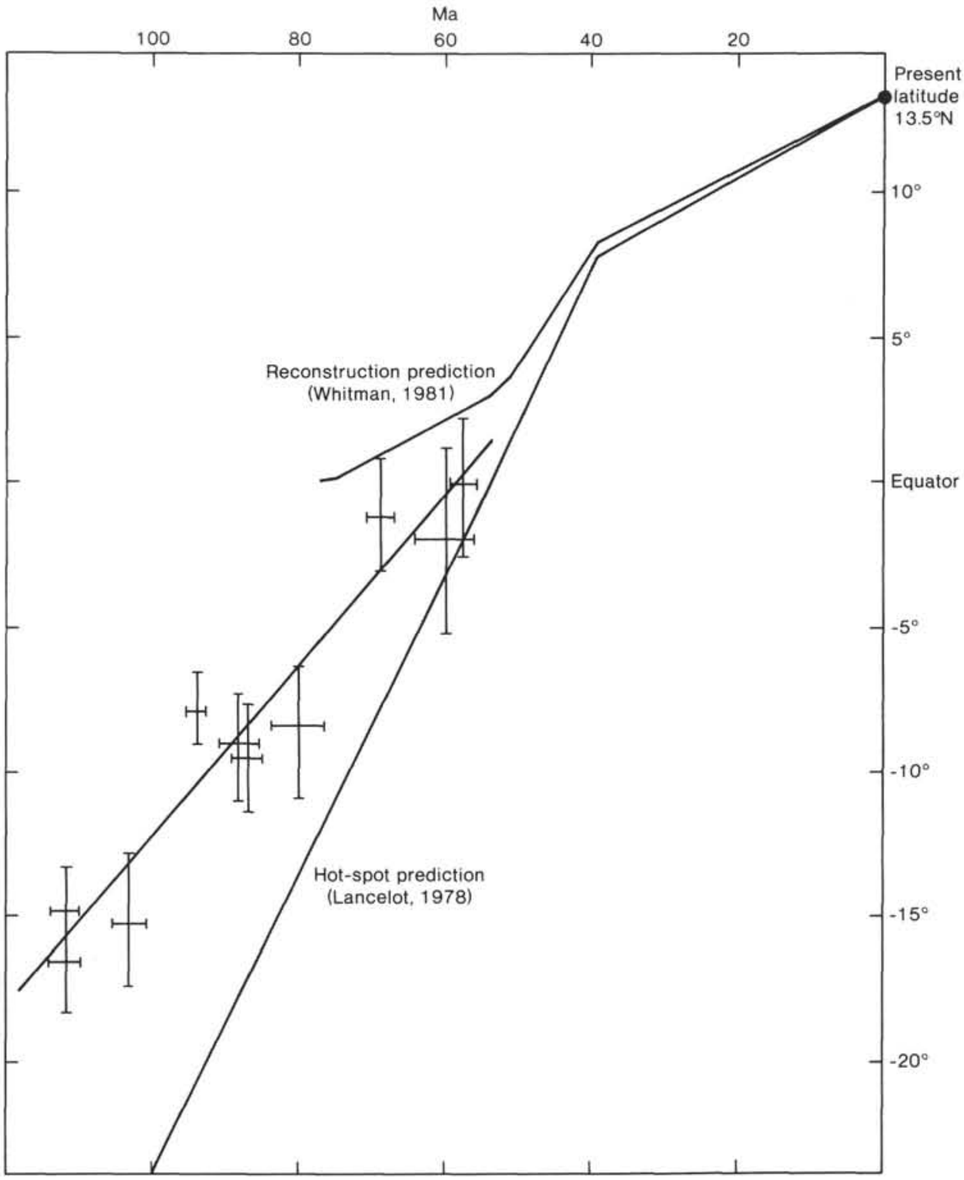

Figure 7. Paleolatitudes of Site 585 plotted with the time scale of Harland et al., 1982. A northward drift of about 30 km/m.y. is indicated as a possible fit of the three clusters of paleolatitudes. For comparison, the predicted paleolatitudes of Site 585—using the hot-spot model of Lancelot (1978) and using the Pacific-Plate-motion model of Whitman (1981), derived from global reconstructions—are shown.

by the set of minicores. In Figure 7 the error bars on the paleolatitudes are the standard deviations (63% confidence intervals) rather than the 95% confidence intervals.

The paleolatitude determinations for the two holes coincide very well. This agreement supports the validity of the composite paleolatitude curve (Fig. 7).

Owing to the poor recovery of some intervals and the discontinuous sedimentation history of Site 585, the Cretaceous paleolatitude determinations cluster into three age groups: (1) a Paleocene-Maestrichtian group centered at about 1°S latitude, (2) a Santonian-Turonian (plus some Campanian and Cenomanian) cluster centered at about 7°S latitude, and (3) an Albian-late Aptian cluster centered at 15°S latitude. The sediment recovery and the paleomagnetic sampling at Site 585 were inadequate to derive reliable paleolatitudes for the Campanian, Cenomanian, or Tertiary. It cannot be determined, therefore, whether Site 585 had a constant northward drift during the Cretaceous or experienced episodes of rapid movement between relative standstills. An average northward drift rate of 30 km/m.y. (3.0 cm/yr.) fits the three clusters (Fig. 7 and 8). This average Cretaceous value is less than the 50 km/m.y. predicted for Site 585 by Lancelot's (1978) Pacific hot-spot model, but is greater than the rate indicated by Whitman's (1981) model for the latest Cretaceous and early Tertiary paleolatitudes derived from reconstructions at several magnetic anomalies (Fig. 8). The hot-spot model lacks reliable paleolatitude/age control points for the mid- and Late Cretaceous, so deviation between the observed paleolatitudes of the western central Pacific and the hot-spot predic-

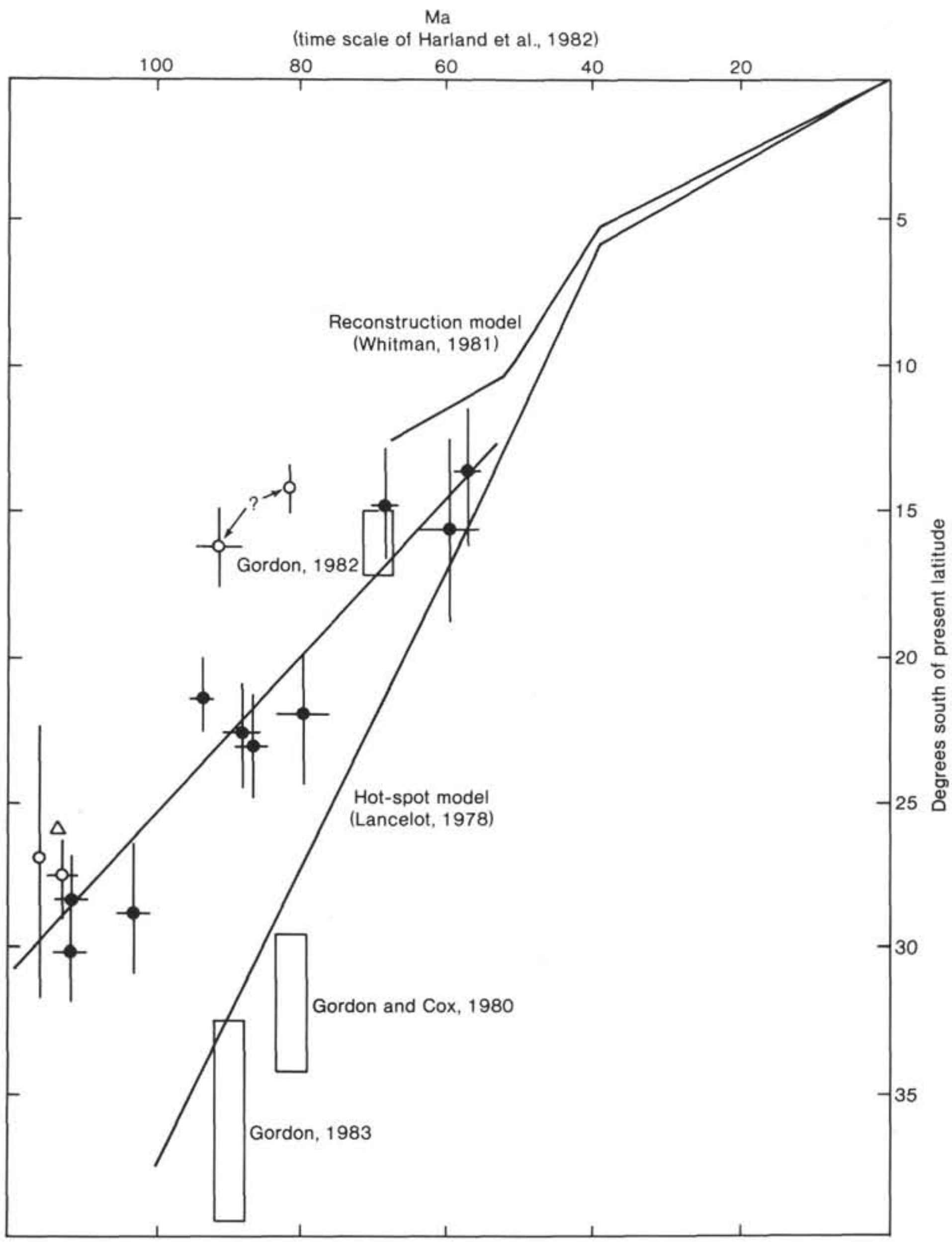

Figure 8. The amount of northward drift of the Western Pacific, as computed from the paleolatitudes of Sites 585 (solid dots), 462 (open dots), and 289 (open triangle), relative to the present latitude of those sites. For comparison, the predicted amounts of northward drift for the location of Site 585 from the Pacific poles (boxes) computed by Gordon (1980), Gordon and Cox (1982), and Gordon (1983), from the hot-spot model (lowermost line) of Lancelot (1978), and from the reconstruction model (uppermost line) of Whitman (1981) are also plotted.

tions cannot be taken as conclusive proof of drift between the hot-spot and geomagnetic reference frames ("true polar wander").

Comparison with other Paleolatitudes from DSDP Sites in the Western Central Pacific

In addition to these studies at Site 585 in the Mariana Basin (13.5°N, 156.8°E), paleomagnetic studies have also been performed at Site 462 in the adjacent Nauru Basin (7.2°N, 165.0°E) (Steiner, 1981a, b; Ogg in Site 462 report, this volume) and at Site 289 on the Ontong-Java Plateau (0.5°S, 158.5°E) (Hammond et al., 1975). These regions of the western central Pacific are considered to be fixed relative to each other, so the data sets can be integrated to derive the latitudinal component of motion of the western central Pacific from the Aptian to the present (Fig. 8). An implicit assumption is that rotation of the Pacific Plate during this interval has been negligible.

The previous studies did not incorporate proper statistical methods, so the procedure of Kono (1980b) was applied to the published data. The stable inclinations upon progressive AF demagnetization (Steiner, 1981a) for lower Campanian through Cenomanian claystones of Holes 462 and 462A were combined for two age intervals: early Campanian (omitting an excursion interval and two samples of uncertain polarity), and a combined Santonian-Cenomanian interval. Steiner did not compute corrections for the deviation of the holes from vertical (Hole 462 had a measured 3-4° deviation and Hole 462A had 1.3-1.5° [Shipboard Scientific Party, 1981]). The resulting paleolatitudes indicate less northward drift than do the paleolatitudes computed from sediments of the same age from Holes 585 and 585A (Fig. 8). The reason for this discrepancy is unknown; the lack of thermal demagnetization of the Site 462 samples may be one factor, although Steiner did not observe any significant effects of thermal treatment on eight pilot samples (following 400-Oe AF demagnetization, however).

The basalt flow and sill complex in Hole 462A was assigned an age of Barremian on the basis of radiolarian assemblages found in sediments within the complex (Larson, Schlanger, et al., 1981; de Wever, 1981). These reworked assemblages are reinterpreted by A. Shaaf (in Site 462 report, this volume) as indicating an Aptian age, on the basis of the range of the youngest form. This age is consistent with the uniform normal magnetization of the complex. The mean paleolatitude was computed from the individual mean inclinations of the five flow units (each of which is composed of several flows). Stable inclinations upon progressive AF demagnetization of the samples were determined by Steiner (1981b). Igneous Unit 30 was omitted from this calculation because it has sills within the flows and so was probably thermally remagnetized at a later date. No correction was possible for the deviation of the hole from vertical, but the low 1.3 to 1.5° measured deviation will not introduce a serious error. Continued drilling of the basaltic complex at Hole 462A during Leg 89 recovered numerous flow units. The paleolatitudes computed from this set of flows (Ogg in Site 462 report, this volume) are nearly identical to the results computed from Steiner's data.

Coring at DSDP Site 289, on the Ontong-Java Plateau, recovered a thick Tertiary and uppermost Cretaceous carbonate section overlying Aptian limestone and basalt. Twenty-six samples of lower Oligocene to upper Campanian and Aptian sediments and seven samples of basalt were analyzed by Hammond et al. (1975) using AF demagnetization. A true mean paleolatitude was computed from the one tuff and three limestone samples of Aptian age. Even though the samples are too few to permit computation of a reliable paleolatitude, the northward drift is essentially identical to the results for Holes 585, 585A, and 462A (Fig. 7). The basalt-core data were not used, because only a single flow was sampled; the 33° of northward drift indicated by these samples is, however, within the 95% confidence interval of the Site 585 results.

The agreement of the amount of northward drift since the Aptian, as computed for the Site 585 turbidites, Site 462 basalts, and Site 289 limestones and tuff, indicates the reliability of the paleolatitudes computed by paleomagnetism for the western central Pacific.

Comparison with Other Pacific Paleomagnetic Poles

Several paleomagnetic poles have been computed for the Pacific Plate by combining data sets for DSDP sites, models of seamount magnetism, and skewness of marine magnetic anomalies. Gordon (1982) computed a late Maestrichtian (~69 Ma) paleomagnetic pole for the Pacific Plate at 71°N, 9°E, which would predict a paleolatitude for Site 585 of 2.7°S (95% confidence interval of 2°). This paleolatitude compares well with the value of 3°S projected for Site 585 by a steady 30-km/yr. rate of northward drift (Fig. 7 and 8).

On the basis of the magnetic anomalies of four seamounts and the paleomagnetic results from Meiji Seamount, Gordon and Cox (1980) computed an average Campanian (81 Ma; in magnetochron 33R) paleomagnetic pole for the Pacific at 56.5°N, 353.5°E. This pole would predict a paleolatitude of 18.6°S (95% confidence interval of 4°) for Site 585. The paleolatitude at 81 Ma determined for Site 585 is approximately 6.5°S (Fig. 7), or possibly 8.5°S ± 2.2° if the average Campanian-Santonian value of Hole 585 is used. Therefore, Site 585 was 10 to 12° farther north than predicted by Gordon and Cox.

Gordon (1983) computed Pacific paleomagnetic pole for 90 Ma (Cenomanian) at 54°N, 334°E, which would predict a paleolatitude for Site 585 of 22.5° (95% confidence interval of 6°). The observed value is tightly constrained to be 9°S (±2.5°) (Fig. 7). Therefore, during the Cenomanian, the site was about 13.5° farther north than predicted by the pole of Gordon (1983).

It is beyond the scope of this chapter to attempt to resolve the differences between the predicted paleolatitudes of the Late Cretaceous Pacific and the observed paleolatitudes of the central western Pacific. Perhaps there was differential movement between the western central Pacific and the north and eastern central Pacific (where Gordon's poles are derived) during the Late Cretaceous. The predictions agree with the observed paleolatitude of Site 585 in the Maestrichtian, so such a theoretical displacement would have been completed by that stage. The spurt of rapid northward motion of the Pacific Plate during the mid-Late Cretaceous, postulated by Gordon (1983), is not apparent in the data from Site 585 or Site 462. Instead, a fairly constant northward drift component of about 30 km/m.y. fits the late Aptian through early Tertiary results.

Summary

Paleolatitudes were computed for several age intervals (Aptian to early Tertiary) using data obtained on a collection of approximately 250 sedimentary rock minicores from two adjacent holes at Site 585. The results for both holes indicate an average rate of northward drift of approximately 30 km/m.y. The paleolatitude of Site 585 was 15°S during the Albian-late Aptian, 7°S during the Santonian-Turonian, and 1°S during the Paleocene-Maestrichtian. The Albian-late Albian paleolatitude agrees well with data from two other sites in the western central Pacific (Sites 462 and 289). In general, the observed paleolatitudes are north of the positions predicted by a hot-spot model or by data from the north and east Pacific.

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APPENDIX
Inclinations of Characteristic Directions, Polarity and Reliability Rating for Paleomagnetic Samples

Lithologic unit, age	Core-Section, interval in cm	Inclination of characteristic direction (degrees)	Polarity	Reliability/comments	
Hole 585					
Unit 2	15-1, 53	14.1	R	B	
l. Paleoc.	15-1, 65	3.5	R	A	
	15-1, 80	−7.5	R	A	
	15-1, 123	7.8	R	A	
	16-1, 4	8.1	N	B	
	16-1, 38	6.8	N	A	
	16-1, 72	1.0	R	B	
Maest.	16-1, 113	1.0	N	A	
	16-1, 129	−1.1	N	A	
	17-1, 58	10.1	N	A	
	17-1, 118	1.3	N	A	
	17-1, 145	−1.0	N	A	
	17-2, 12	−4.8	N	A	
Unit 3	18-1, 28	26.5	?	C	Overprint
	18-1, 63	0.5	N	A	
	18-1, 70	1.0	N	A	
	18-1, 137	0.3	N	A	
	18-2, 6	−11.2	N	A	
	19-1, 6	6.3	N	A	
	19-1, 38	13.2	N	A	
	20-1, 14	−17.3	N	A	
	20-2, 49	−14.4	N	A	
	20-2, 89	−18.5	N	A	
l. Camp.	20-3, 12	−8.3	N	A	
	20-3, 91	−11.8	N	A	
	20-3, 141	−11.2	N	A	
Unit 4					
Camp.	21-1, 20	−3.4	N	A	
	21-1, 45	−2.2	N	A	

Appendix (continued).

Lithologic unit, age	Core-Section, interval in cm	Inclination of characteristic direction (degrees)	Polarity	Reliability/comments	
Hole 585 (Cont.)					
Sant.	26-1, 69	−23.1	N	A	
Subunit 5a	27-1, 27	−3.3	N	A	
	27-1, 59	−0.7	N	A	
	27-1, 130	−35.3	N	A	
	27-2, 26	−7.0	N	B	
	27-2, 100	−34.1	N	A	
	27-3, 50	16.4	R?	C	
	27-3, 103	7.1	R?	C	
	27-4, 4	−37.5	N	A	
	28-1, 73	−10.8	N	A	
	28-1, 122	−10.5	N	A	
	28-2, 62	−4.5	N	B	
	28-2, 133	−5.2	N	B	
	28-3, 87	−7.3	N	A	
	28-3, 146	−4.5	N	A	
	28-4, 69	−9.4	N	A	
	28-4, 112	−14.3	N	A	
	28-5, 8	−22.0	N	A	
	28-5, 34	−15.8	N	A	Was inverted
Sant.-Coniac.					
Subunit 5b	29-1, 74	−18.8	N	A	
	29-1, 116	0.5	N	A	
	29-2, 52	3.9	N	A	
	29-2, 81	−21.2	N	A	
Tur.	30-1, 19	−28.2	N	A	
	30-1, 26	−22.8	N	A	
	30-1, 125	−14.6	N	A	
	31-1, 28	−16.4	N	A	
	31-1, 96	−5.6	N	A	
	31-2, 62	−6.2	N	A	
	31-2, 68	−6.2	N	A	
	31-3, 142	−13.4	N	A	
	31-4, 21	−34.6	N	B	
	31-4, 58	−15.3	N	A	
	32-1, 29	−17.7	N	A	
	32-1, 75	−19.6	N	A	
	32-2, 107	−12.8	N	A	
l. Cenom.	32-3, 113	−11.2	N	A	
	32-4, 11	−10.2	N	A	
	32-4, 81	−7.3	N	A	
	32-5, 7	−12.0	N	A	
m. Cenom.					
Subunit 5c	34-1, 30	−14.7	N	A	
	34-1, 41	−10.7	N	B	
	34-1, 54	−10.0	N	B	
	34-1, 75	−11.1	N	B	
	34-2, 18	−18.5	N	B	
	34-2, 119	−15.9	N	A	
	34-3, 41	−15.4	N	A	
	35-1, 24	−5.7	N	A	
	35-1, 72	−12.4	N	B	
	35-2, 16	−6.9	N	A	
	35-2, 47	−17.8	N	A	
	35-2, 78	−8.8	N	A	Was inverted
l. Albian	36-1, 24	−22.7	N	A	
	36-1, 43	−21.0	N	A	
m. Albian	37-1, 17	−34.2	N	A	
Subunit 6a	39-1, 37	−20.5	N	A	
	42-1, 10	−33.3	N	B	
	42-1, 50	−24.6	N	B	
	42-2, 57	−31.7	N	A	
Subunit 6b	43-1, 20	−28.7	N	A	
	43-2, 7	−16.7	N	A	
	43-4, 130	−18.6	N	A	
	43-5, 72	−2.8	N	B	Drift
	44-1, 120	−11.2	N	A	
	44-2, 32	−26.0	N	A	
	44-3, 67	−11.8	N	B	Drift
	44-4, 62	−20.0	N	B	
	44-5, 103	−35.6	N	B	Sandstone
	45-1, 36	−41.0	N	A	
	45-2, 94	−27.5	N	A	
	45-3, 59	−13.1	N	A	
	45-3, 114	−28.0	N	A	
e. Albian	46-1, 68	−24.9	N	A	
	46-2, 91	−24.1	N	A	
	46-3, 42	−37.3	N	A	
	46-4, 76	−20.7	N	A	
	47-1, 27	−40.3	N	A	

Appendix (continued).

Lithologic unit, age	Core-Section, interval in cm	Inclination of characteristic direction (degrees)	Polarity	Reliability/ comments
Hole 585 (Cont.)				
	47-1, 52	-50.8	N	B Sandy
	47-2, 32	-41.9	N	B Drift
	47-2, 128	-39.2	N	B Drift
	47-3, 5	-40.7	N	A
	47-4, 28	-33.7	N	A
	49-1, 52	-18.6	N	A
	49-3, 73	-39.8	N	A
	49-5, 109	-31.7	N	A
	69-4, 74	-21.3	N	A
	50-1, 135	-25.3	N	A
	50-2, 39	-14.2	N	A
	50-2, 71	-13.8	N	A
	50-3, 68	-28.1	N	A
	50-3, 85	-21.5	N	B
	50-4, 8	-19.3	N	A
	51-1, 96	-8.7	N	B
	51-2, 51	-17.4	N	B
	51-3, 13	-19.4	N	A
	51-3, 75	-25.7	N	A
	51-4, 25	-44.8	N	A
e. Alb.- l. Apt.	52-1, 115	-25.9	N	A
	52-2, 130	-25.2	N	A
	52-3, 31	-30.8	N	A
	53-2, 94	-25.8	N	A
	54-2, 85	-29.3	N	B
	54-3, 41	-24.2	N	A
	55-1, 5	21.1	?	C Inverted?
	55-1, 79	-20.6	N	A
	55-2, 117	-34.5	N	B Drift
	55-4, 40	-14.1	N	A
	55-5, 30	-45.0	N	B Drift
	55-5, 78	-30.3	N	A
Hole 585A				
Unit 1 e. Miocene	H1-1, 67	10.8	N	B
	H1-1, 92	13.6	N	B
	H1-1, 113	8.2	N	B
	H1-1, 133	9.5	N	B
Unit 2 e. Eocene	H1-2, 104	-7.5	N	A
Paleoc.	1-1, 66	22.9	N?	C (Chron 24?)
	1-1, 91	25.0	R?	C (25R?)
	1-1, 122	10.0	N?	C (Chron 25?)
	1-1, 138	-1.5	N?	C
	1-2, 17	6.0	R	A
	2-1, 16	-6.6	N	B (Chron 28?)
	2-1, 30	-6.0	N	B
	2-1, 59	4.5	N	B
	2-1, 90	-5.5	N	B
	3-1, 37	15.8	N	B (Chron 29?)
Maest.	3-1, 123	8.2	N	B
	3-2, 19	-19.5	N	A
Unit 5 Santonian	5-1, 47	-12.4	N	A
	5-1, 113	-9.3	N	A
	5-2, 17	-18.9	N	A
	5-2, 123	-6.8	N	A
	6-1, 145	-10.2	N	A
	6-2, 9	-17.1	N	A
	6-2, 37	-7.0	N	A
Turonian	7-1, 23	-9.6	N	A

Appendix (continued).

Lithologic unit, age	Core-Section, interval in cm	Inclination of characteristic direction (degrees)	Polarity	Reliability/ comments
Hole 585A (Cont.)				
	7-2, 71	-8.2	N	A
	7-3, 39	-7.2	N	A
	7-4, 37	10.6	N?	C Inverted?
	8-1, 57	-18.6	N	A
	8-1, 102	-23.4	N	A
	8-2, 9	-32.1	N	A
	8-2, 30	-25.1	N	A
	8-2, 109	-25.2	N	A
l. Cenom.	9-1, 118	-0.6	N	B
	9-2, 13	-29.2	N	B Was inverted
	10-1, 48	-21.3	N	A
Unit 6 e. Albian	H5-1, 31	-29.5	N	B
	H5-1, 65	-18.8	N	B
	H5-2, 3	-39.6	N	B
	H5-3, 41	-23.9	N	A
	H5-3, 99	-20.8	N	A
	H5-3, 134	-28.6	N	A
	H5-4, 26	-14.6	N	A
	H5-4, 97	-29.6	N	A
	H5-4, 141	-38.7	N	B
	H5-5.4	-28.5	N	A
l. Aptian	11-1, 133	-36.1	N	A
	11-2, 30	-45.8	N	B
	11-4, 92	-3.2	N	A
	11-4, 139	-17.2	N	A
	11-5, 57	-39.5	N	B
	12-3, 121	-29.5	N	B
	12-4, 35	-29.0	N	A
	12-4, 130	-34.3	N	A
	12-5, 42	-25.4	N	A
	12-5, 93	-29.8	N	B
	12-6, 95	-28.5	N	A
	13-1, 80	-34.9	N	A
	13-1, 130	-24.5	N	A
	13-2, 64	-34.1	N	A
	13-3, 86	-30.2	N	A
	14-3, 12	-27.8	N	A
	14-3, 56	-27.4	N	B
	14-4, 64	-20.2	N	A
	14-4, 72	-14.1	N	A
	14-4, 94	-23.0	N	A
	14-4, 135	-38.5	N	A
	14-5, 56	-14.5	N	B
	15-2, 18	-37.4	N	A
	15-3, 10	-19.6	N	A
	15-3, 127	-20.3	N	A
	15-4, 120	-35.1	N	A
	15-5, 123	-12.1	N	A
	16-1, 16	-27.3	N	A
	16-1, 114	-26.2	N	A
	16-2, 48	-39.8	N	B
	16-2, 125	-33.4	N	A
	16-3, 123	-39.5	N	B
	16-4, 21	-41.7	N	B
	17-1, 22	-41.5	N	B
	17-1, 138	-42.5	N	B
	17-4, 27	-30.6	N	B
	17-4, 43	-32.8	N	A
	17-4, 47	-38.2	N	B
	17-5, 8	-39.3	N	A
	18-1, 30	-37.3	N	B
	21-1, 29	-42.8	N	B
	21-2, 125	-39.3	N	B
	22-1, 99	-73.5	N	C Sandstone